# Manure Management Guidelines

**Province of British Columbia**
Ministry of Agriculture and Food

*prepared by:*

Mr. R. A. Bertrand, P.Ag.
Soils Branch
B.C. Ministry of Agriculture and Food

Dr. N. R. Bulley, P.Eng.
Department of Bio-Resource Engineering
University of British Columbia

1985

# PREFACE

The Manure Management Guidelines have been written as a technical, reference document for use in assisting producers to determine the rate of various animal manures required to provide adequate nutrition for various crops. The main objectives are to promote nitrogen conservation and use in an agronomically and environmentally sound manner.

Most of the values contained in the Guidelines were produced by a nitrogen behaviour simulation model developed under the direction of Dr. N.R. Bulley at the University of British Columbia and funded by the Demonstration of Agricultural Technology and Economics (D.A.T.E.) program of the B.C. Ministry of Agriculture and Food. The authors wish to acknowledge the following people for their valuable assistance in developing the model, preparing the Guidelines, and providing criticism and suggestions: Dr. A.A. Bomke, Dr. B. Cappelaere, Dr. M. Khan, Dr. E. Barber, Mr. P. Johnson, Mr. R. Van Kleeck, Dr. G. Kowalenko, Mr. R. Sera, Ms. T. Delaurier, Mr. R.C. Wood, and Ms. J. Lee.

# TABLE OF CONTENTS


Page

**INTRODUCTION** ..... 1
— Conserving and Utilizing Manure
— Minimum Loss System Concept

**BASIC MINIMUM LOSS SYSTEM** ..... 3
1. Dairy ..... 3
2. Swine
   a) Grower/Finisher ..... 3
   b) Weaner ..... 4
   c) Farrow to Finish ..... 5
3. Poultry
   a) Layers ..... 6
   b) Broilers ..... 6

**MANURE APPLICATION RATES (minimum loss systems)** ..... 8

APPLICATION RATES ADJUSTMENT FACTORS ..... 9
— Soil Nitrogen ..... 10
— Collection and Storage ..... 10
— Time of Year of Application and Type of Soil ..... 10
— Method of Spreading ..... 11
— Location of Farm ..... 11

Page

CALCULATION OF MANURE APPLICATION RATE (FARM SPECIFIC) ..... 11

**VOLUME OF MANURE IN STORAGE AND SPREADER LOADS PER HECTARE** ..... 14

**INORGANIC FERTILIZER REQUIREMENT** ..... 16

**DETERMINING THE MOST EFFICIENT COMBINATION OF MANURE AND INORGANIC FERTILIZER** ..... 17

**PHOSPHORUS AND POTASSIUM** ..... 20

**LIST OF REFERENCES** ..... 22

**APPENDICES** ..... 23
— APPENDIX A: CALCULATION SHEETS ..... 24
— APPENDIX B: MANURE MANAGEMENT DATA SHEET ..... 35
— APPENDIX C: CONVERSION FACTORS ..... 37
— APPENDIX D: PERCENT LOSS IN NITROGEN CONTENT OF MANURE CORRESPONDING TO VARIOUS LOSS FACTORS ..... 39

# LIST OF TABLES


| | | Page |
|---|---|---|
| 1. | Dairy Minimum Loss System Description Summary | 3 |
| 2. | Milk Production Factors | 3 |
| 3. | Grower/Finisher Minimum Loss System Description Summary | 4 |
| 4. | Weaner Minimum Loss System Description Summary | 4 |
| 5. | Weaner Production Factors (Production/ Sow Place) | 4 |
| 6. | Farrow to Finish Minimum Loss System Description Summary | 5 |
| 7. | Finisher Production Factors (Production/ Sow Place) | 5 |
| 8. | Layer Minimum Loss System Description Summary | 6 |
| 9. | Broiler Minimum Loss System Description Summary | 6 |
| 10. | Minimum Loss Application Rates for Two Crops | 8 |
| 11. | Yield and Nitrogen Removal Values for Selected Crops | 9 |
| 12. | Soil Nitrogen Adjustment Factors | 10 |
| 13. | Loss Factors Due to Collection and Storage | 10 |
| 14. | Loss Factors Due to Time of Application for Medium to Fine Textured Soil | 10 |
| 15. | Loss Factors Due to Method of Spreading | 11 |
| 16. | Loss Factors Due to Farm Location Other Than Abbotsford | 11 |
| 17. | Calculation of Manure Units Required | 11 |
| 18. | Calculation of Manure Units in Storage | 15 |
| 19. | Phosphorus and Potassium Applied in Dairy Manure | 20 |
| 20. | Phosphorus and Potassium Applied in Swine Manure | 20 |
| 21. | Phosphorus and Potassium Applied in Poultry Manure | 21 |
| 22. | Nitrogen, Phosphate, and Potash Content of One Manure Unit of Various Manures That Have Been Managed as Described for the Various Minimum Loss Systems | 21 |
| 23. | Volume and Weight of One Manure Unit of Various Manures as Excreted | 21 |


# PLATES


| | | |
|---|---|---|
| 1. | Manure application using subsurface injection | 2 |
| 2. | Covered, impervious manure holding structure | 2 |
| 3. | Impervious structure for slurry storage | 7 |
| 4. | Earthen lagoon storage of liquid manure | 7 |
| 5. | Subsurface injection | 12 |
| 6. | High spray vacuum tanker | 12 |
| 7. | Spray irrigation equipment used for spreading liquid manure | 13 |
| 8. | Surface application without incorporation results in high nitrogen losses | 13 |

# MANURE MANAGEMENT GUIDELINES

## INTRODUCTION

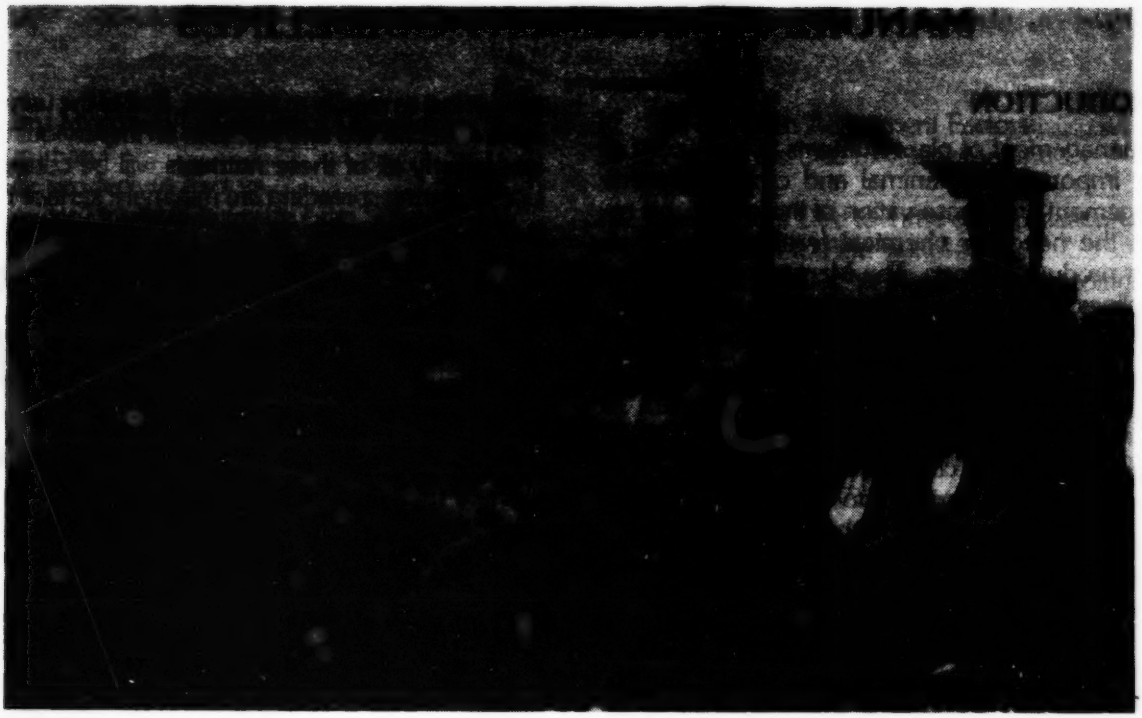
The management of plant nutrients in manure is of major importance to animal and crop producers. Management and conservation of these nutrients reduces the need for chemical fertilizers and thus lowers production costs. The Manure Management Guidelines are designed to assist the producer in conserving and utilizing manure nutrients by:

1. Indicating the effects that different management systems have on nutrient content of manures.
2. Detailing how changes in manure spreading and incorporation methods affect the amount of nutrients supplied to the crop.
3. Assisting producers in determining application rates required to achieve a desired crop yield.
4. Ensuring that application rates do not cause undue losses of nitrogen to groundwater.

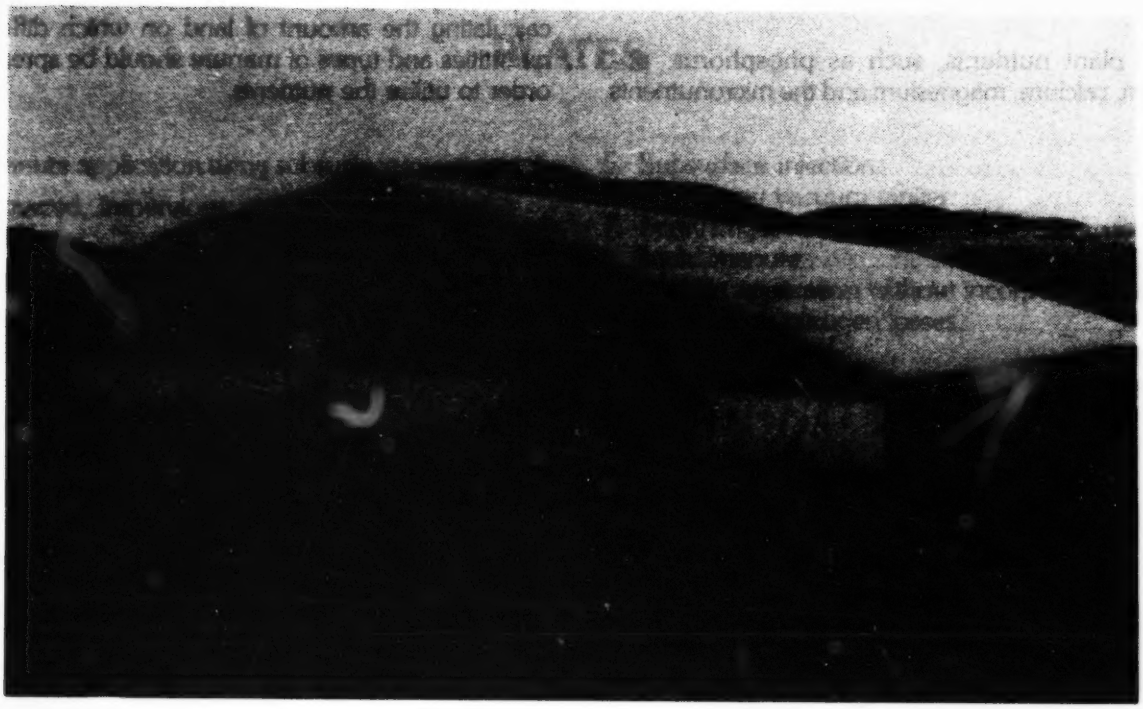
The plant nutrient of greatest concern is nitrogen. Losses of nitrogen during handling, storage, and spreading can be extensive. Also, losses from soil due to leaching or denitrification are of concern, especially in coastal regions of B.C. The guidelines indicate the effect of various management systems on nitrogen losses.

Other plant nutrients, such as phosphorus, potassium, calcium, magnesium and the micronutrients are not lost as readily as nitrogen. If all of the urine and feces are collected and stored in an impervious structure, nearly all of these nutrients will be conserved. Losses during spreading are minimal if surface runoff is prevented. Leaching losses of phosphorus, potassium, calcium and magnesium are minimal in most soils. The best method of ensuring that optimum levels of these nutrients are in the root zone is through an annual soil test and adherence to the recommendations in the soil analysis report.

To encourage nitrogen conservation and utilization, the Manure Management Guidelines are based on a manure management system which will keep nitrogen losses to a minimum (a Minimum Loss System). Each on-farm system can then be compared to the Minimum Loss System to determine where the two systems differ. Handling, storage and/or spreading methods which differ from those described for the Minimum Loss System normally result in greater nitrogen losses. Factors indicating the increase in the amount of loss are provided for each component of the management system. Adjusting the Minimum Loss System by the appropriate factors will determine the rate of manure application required for optimum plant growth. A table is provided to assist in calculating the amount of land on which different quantities and types of manure should be spread in order to utilize the nutrients.



*1. Manure application using subsurface injection.*



*2. Covered, impervious manure holding structure.*

# THE BASIC MINIMUM LOSS SYSTEM

## 1. DAIRY

The dairy minimum loss system, summarized in Table 1, is designed for management systems on a yearly basis. That is, milk and manure production are calculated for 365 days which, under a normal 305 day lactation period, is the production from 1.2 cows (or one cow place). On this basis, it is assumed that each 640 kg cow place in the milking herd consumes 164 kg N, produces 9250 kg milk containing 48 kg N, and excretes 116 kg N in the manure (including both urine and feces). Nitrogen losses occur during collection of the manure (10%), six months storage (10%), and during land application via injection (5%). This means that about 90 kg of the original 116 kg of nitrogen excreted by each cow place enters the soil.

The minimum loss system described is for a relatively high producing herd. If the feed intake or milk production are lower than that described, the quantity of nitrogen in the manure will be lower and manure additions for crop production will have to be higher. Table 2 provides factors for adjusting the manure application rate according to milk production values.

**TABLE 1: DAIRY MINIMUM LOSS SYSTEM DESCRIPTION SUMMARY**

| | |
|---|---|
| **LOCATION:** | Abbotsford:<br>— yearly precipitation 1440 mm<br>— potential evapotranspiration 580 mm |
| **FARM SYSTEM:** | Holstein Cows: 640 kg<br>Milk Production: 9250 kg (48 kgN) $yr^{-1}$ or 25.3 kg $day^{-1}$<br>Feed Intake: each milking cow place ingests 164 kg N $yr^{-1}$ and excretes 116 kg N $yr^{-1}$ in the manure [5]* |
| **MANURE HANDLING:** | — daily collection<br>— covered, impervious structure<br>— manure applied by subsurface injection in early April |
| **SOIL:** | Abbotsford Silt Loam:<br>— organic nitrogen content of top 20 cm is 0.2%<br>— soil is 1.3 m deep<br>— water table remains below 1 m throughout the year |
| **MANURE UNIT:** | Quantity of manure excreted by one cow place (1.2 animals) in the milking herd per year. |

* Numbers in [ ] refer to references on page 22.

**TABLE 2: MILK PRODUCTION FACTORS**

| Herd Average Milk Production | | | Adjustment |
|---|---|---|---|
| kg/day | kg/305 days | kg/365 days | Factors |
| 20 | 6100 | 7300 | 1.27 |
| 21 | 6405 | 7665 | 1.2 |
| 22 | 6710 | 8030 | 1.15 |
| 23 | 7015 | 8395 | 1.1 |
| 24 | 7320 | 8760 | 1.06 |
| 25.3 | 7716 | 9250 | 1.0 |

## 2. SWINE

On many swine operations, boars, sows, litters, weaner pigs and finishers all contribute to the manure collected. Three types of swine operations are detailed in the sections following:

a) Grower/Finisher
b) Weaners
c) Farrow to Finish

### a) Grower/Finisher

The minimum loss system for a finishing barn, summarized in Table 3, is designed for management systems on a yearly basis. Pork and manure production are calculated for 365 days which is the production from 3.5 grower/finishers (this is equivalent to one pig place and the pig place is filled throughout the whole year). This is based on the assumption that 15 weeks are required for each animal to grow from weaner stage (10 weeks old, 20 kg) to finished pig (100 kg). It is also assumed that each animal consumes 275 kg of 16% protein feed over this growing period. This provides 7 kg N of which approximately 2 kg N is assimilated into body tissue and 5 kg N is excreted in the manure (including both urine and feces). As 3.5 growing cycles are completed over the year, one pig place will excrete about 17.5 kg N $yr^{-1}$. The length of time required to produce a finished pig will vary from 13 to 18 weeks depending on rate of feed conversion of the animals. However, the amount of N excreted per pig place will not vary significantly. Therefore, "Production Factors" are not provided for grower/finisher pigs even though the number of pigs marketed per year may vary considerably.

Nitrogen losses occur during manure collection (10%), six months storage (10%) and application via injection (5%). Around 13.2 kg of the original 17.5 kg N excreted by each pig place enters the soil.

**TABLE 3: GROWER/FINISHER MINIMUM LOSS SYSTEM DESCRIPTION SUMMARY**

| | |
|---|---|
| **LOCATION:** | Abbotsford:<br>— yearly precipitation 1440 mm<br>— potential evapotranspiration 580 mm |
| **FARM SYSTEM:** | Finishing Operation:<br>— each animal grows from 20 kg to 100 kg in 15 weeks<br>— finished pigs are marketed at 25 weeks of age<br>— feed intake is 275 kg of 16% protein feed during finishing operation, and each grower/finisher place excretes 17.5 kg N $yr^{-1}$ [4] |
| **MANURE HANDLING:** | — daily collection<br>— covered, impervious structure<br>— manure applied by subsurface injection in early April |
| **SOIL:** | Abbotsford Silt Loam:<br>— organic nitrogen content of top 20 cm is 0.2%<br>— soil is 1.3 m deep<br>— water table remains below 1 m throughout the year |
| **MANURE UNIT:** | Quantity of manure excreted by one grower/finisher place (3.5 animals) per year. |

**TABLE 4: WEANER MINIMUM LOSS SYSTEM DESCRIPTION SUMMARY**

| | |
|---|---|
| **LOCATION:** | Abbotsford:<br>— yearly precipitation 1440 mm<br>— potential evapotranspiration 580 mm |
| **FARM SYSTEM:** | Weaner Operation<br>— each breeding sow produces 18.4 weaners per year<br>— piglets grow from 5 kg at 5 weeks of age to 20 kg at 10 weeks, at which time they are marketed<br>— each sow place consumes about 50 kg N in feed per year and excretes 36 kg N $yr^{-1}$ [4] |
| **MANURE HANDLING:** | — daily collection<br>— covered, impervious structure<br>— manure applied by subsurface injection in early April |
| **SOIL:** | Abbotsford Silt Loam:<br>— organic nitrogen content of top 20 cm is 0.2%<br>— soil is 1.3 m deep<br>— water table remains below 1 m throughout the year |
| **MANURE UNIT:** | Quantity of manure excreted per year by one breeding sow and associated piglets, weaner pigs and adult pigs. |

**b) Weaners**

The minimum loss system for a farrow to weaner operation is summarized in Table 4. Sows, boars, litters and weaners all contribute to the manure going to storage. A typical weaner operation having 100 breeding sows present at any one time over the year is assumed to also have present 320 weaner pigs plus:

— 15 open gilts
— 5 sows to be replaced
— 6 boars
= 26 other adult swine

The farm markets 1840 weaner pigs per year. Every sow place is, therefore, defined as 1 sow, 0.26 other adult swine, and 3.2 weaner pigs.

The protein content of feed ingested varies according to type and age of animal. Overall, each sow place consumes about 2.2 metric tonnes of feed (average 14% protein) in one year. This feed contains about 50 kg N and over a year about 36 kg of this nitrogen is excreted per sow place as both urine and feces.

Nitrogen losses during collection (10%), 6 months storage (10%), and application via injection (5%) leaves 27 kg N effectively reaching the soil per sow place.

Variations in the animal distribution of the operation change the N content of the manure collected. This change is insignificant if the number of adult animals per breeding sow is varied. However, changes in the fertility rate of the breeding sows and number of litters per year does affect the composition of manure going to storage.

For example, an average litter size of seven surviving piglets means that only 16 weaners will be marketed per sow place per year and for a 100 sow operation, 280 weaners will be maintained on the farm at any

**TABLE 5: WEANER PRODUCTION FACTORS (PRODUCTION/SOW PLACE)**

| Weaners Present at any one time (per sow place) | Weaners Marketed per year (per sow place) | Adjustment Factor |
|---|---|---|
| 2.4 | 13.8 | 1.10 |
| 2.8 | 16.1 | 1.08 |
| 3.2 | 18.4 | 1.00 |
| 3.6 | 20.7 | 0.95 |
| 4.0 | 23.0 | 0.91 |
| 4.4 | 25.3 | 0.86 |
| 4.8 | 27.6 | 0.81 |

one time. In this case, each sow place excretes 34 kg N in manure. Table 5 provides factors for adjusting the manure application rate according to the number of weaners managed per sow place per year.

### c) Farrow to Finish

A farrow to finish operation has adult swine, litters, weaners and grower/finishers all contributing to the manure collected. Table 6 summarizes the minimum loss system over a one year period for a farrow to finish operation. At 10 weeks of age and weighing 20 kg the weaners are classed as grower/finishers and grow to a weight of 100 kg in 15 weeks, at which time they are marketed.

A typical farrow to finish operation having 100 breeding sows in production over the whole year is assumed to also have present:

— 15 open gilts
— 5 sows to be replaced
— 6 boars
= 26 other adult swine
+ 320 weaners
+ 530 finishers

The operation markets 1840 finished pigs per year.

Based on the above data, one sow place is defined as 1 breeding sow, 0.26 other adult swine, 3.2 weaners and 5.3 finishers. 18.4 finished pigs are marketed per sow place per year.

The overall consumption of feed (averaging 14% protein) per sow place per year is about 8000 kg. This feed provides 180 kg N and, after ingestion and assimilation, 126 kg of this N is excreted in the manure (including both urine and feces). After collection losses (10%), storage losses (10%) and losses due to spreading by injection (5%), about 97 kg N is applied to the soil per sow place per year.

The animal distribution of the farrow to finish operation has a bearing on the nitrogen content of the manure collected. Variations in the number of other adult swine associated with each sow place has little or no effect on the N content of the manure pool. However, the fertility rate of each breeding sow will affect the N content of manure going into storage. Adjustment factors for the manure application rate according to sow fertility are tabulated in Table 7.

**TABLE 6: FARROW TO FINISH MINIMUM LOSS SYSTEM DESCRIPTION SUMMARY**

| | |
|---|---|
| **LOCATION:** | Abbotsford:<br>— yearly precipitation 1440 mm<br>— potential evapotranspiration 580 mm |
| **FARM SYSTEM:** | Farrow to Finish Operation<br>— 18.4 animals are finished and marketed per year per breeding sow place<br>— each sow place consumes 180 kg N in feed each year and excretes 126 kg N $yr^{-1}$ [4] |
| **MANURE HANDLING:** | — daily collection<br>— covered, impervious structure<br>— manure applied by subsurface injection in early April |
| **SOIL:** | Abbotsford Silt Loam:<br>— organic nitrogen content of top 20 cm is 0.2%<br>— soil is 1.3 m deep<br>— water table remains below 1 m throughout the year |
| **MANURE UNIT:** | Quantity of manure excreted by one breeding sow and associated piglets, weaner, grower/finisher, and adult pigs. |

**TABLE 7: FINISHER PRODUCTION FACTORS (PRODUCTION/SOW PLACE)**

| Weaners Present At Any One Time (per sow place) | Finishers Present At Any One Time (per sow place) | Finishers Marketed (per sow place/yr.) | Adjustment Factor |
|---|---|---|---|
| 2.4 | 4.0 | 13.8 | 1.26 |
| 2.8 | 4.6 | 16.1 | 1.11 |
| 3.2 | 5.3 | 18.4 | 1.00 |
| 3.6 | 6.7 | 20.7 | 0.91 |
| 4.0 | 7.3 | 23.0 | 0.83 |
| 4.4 | 7.9 | 25.3 | 0.75 |
| 4.8 | 8.5 | 27.6 | 0.68 |

## 3. POULTRY

Two types of poultry operations are outlined:

a) layers
b) broilers

### a) Layers

The minimum loss system for layers is summarized in Table 8 and is designed for management systems on a yearly basis. Egg and manure production are calculated for 365 days. One bird place corresponds to one 1.8 kg layer which is in production for the entire year. Each bird place consumes 42 kg of 16% protein feed which provides 1.1 kg N per year. Each bird place produces 250 eggs and excretes about 0.8 kg N in the manure. Nitrogen losses occur during collection and storage (40%) and during surface application and immediate incorporation (5%). Thus, about 0.46 kg N per bird place per year effectively reaches the soil.

**TABLE 8: LAYER MINIMUM LOSS SYSTEM DESCRIPTION SUMMARY**

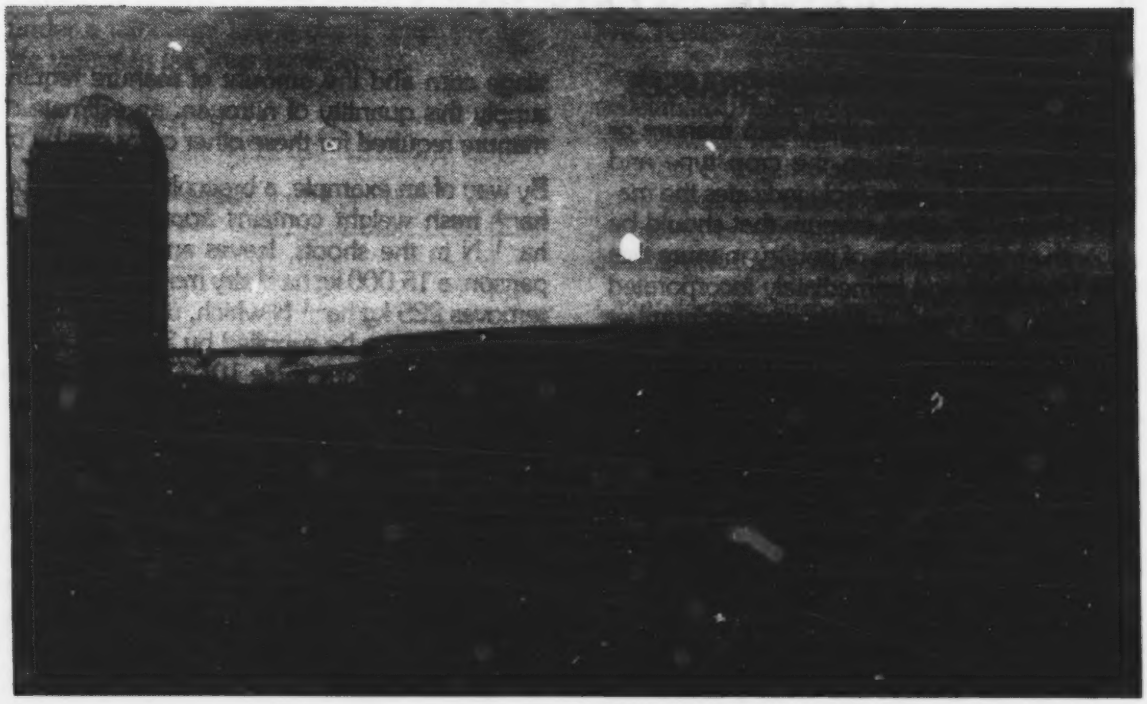
| | |
|---|---|
| **LOCATION:** | Abbotsford:<br>— yearly precipitation 1440 mm<br>— potential evapotranspiration 580 mm |
| **FARM SYSTEM:** | Layer Operation<br>— average bird weight is 1.8 kg<br>— average egg production is 250 eggs per bird per year<br>— each bird consumes 42 kg of 16% [3] protein feed each year and excretes 0.8 kg N $yr^{-1}$ [11] |
| **MANURE HANDLING:** | — manure is collected in a deep pit with no drying fans<br>— storage is for 12 months<br>— manure is surface applied in April and immediately incorporated into the soil after spreading |
| **SOIL:** | Abbotsford Silt Loam:<br>— organic nitrogen content of top 20 cm is 0.2%<br>— soil is 1.3 m deep<br>— water table remains below 1 m throughout the year |
| **MANURE UNIT:** | Quantity of manure excreted per year by each bird in the laying flock. |

### b) Broilers

The minimum loss system for meat type birds, summarized in Table 9, is designed for management systems on a yearly basis. Manure and meat production are calculated for 365 days. It is assumed that a 55 day growing cycle is the time required for a bird to reach a market weight of 1.8 kg. Therefore, one bird place in production over the entire year corresponds to 6.7 cycles, or 6.7 birds sent to market in that year. Each bird marketed consumes 4.5 kg of 22% protein feed. This means that each bird place consumes about 1.1 kg N per year of which about 0.5 kg is assimilated into body tissue and 0.6 kg N is excreted. Nitrogen losses occur during collection and storage (20%) and during surface application and immediate incorporation (5%). About 0.46 kg of the nitrogen excreted per bird place per year enters the soil.

**TABLE 9: BROILER MINIMUM LOSS SYSTEM DESCRIPTION SUMMARY**

| | |
|---|---|
| **LOCATION:** | Abbotsford:<br>— yearly precipitation 1440 mm<br>— potential evapotranspiration 580 mm |
| **FARM SYSTEM:** | Broiler Operation<br>— each bird grows to a marketable weight of 1.8 kg in 55 days<br>— 6.7 growing cycles are carried out each year<br>— each bird place consumes 4.5 kg of 22% protein feed each year and excretes 0.6 kg N $yr^{-1}$ in the manure [11] |
| **MANURE HANDLING:** | — manure drops to sawdust covered floor<br>— manure is removed after each growing cycle and is stored in a covered, naturally ventilated shed<br>— application is to the soil surface followed by immediate incorporation |
| **SOIL:** | Abbotsford Silt Loam:<br>— organic nitrogen content of top 20 cm is 0.2%<br>— soil is 1.3 m deep<br>— water table remains below 1 m throughout the year |
| **MANURE UNIT:** | Quantity of manure excreted per year by one bird place (6.7 birds marketed per year). |



*3. Impervious structure for slurry storage.*

*4. Earthen lagoon storage of liquid manure.*

# MANURE APPLICATION RATES

## 1. SILAGE CORN AND FORAGE GRASSES

The quantity of nitrogen required from manure or inorganic fertilizer depends on the crop type and potential yield. The following table indicates the manure units of dairy or swine manure that should be injected, or the manure units of poultry manure that should be broadcast and immediately incorporated to achieve a desired yield. The appropriate number should be entered on line (5) of Table 17 on page 11. This rate of manure will supply some phosphorus and potassium. Tables 19, 20, 21 and 22 on pages 20 and 21 provide information on quantities of P and K contained in various types of manure and for different rates of application.

## 2. OTHER CROPS

A nitrogen behaviour computer model was used to generate the values which appear in Table 10 for corn and grass. Within the model there are programs that simulate the growth of these two crops. Other crops also receive manure on a routine or periodic basis and there is a need for information on the amount of manure nitrogen required by these other crops.

However, at this time there are no programs within the nitrogen behaviour model which simulate growth of crops other than silage corn and grasses. In Table 11 nitrogen removal values have been provided for two yield levels of a range of crops. By comparing these values with the amount of nitrogen removed by silage corn and the amount of manure required to supply this quantity of nitrogen, an estimate of the manure required for these other crops can be made.

By way of an example, a broccoli yield of 12,000 kg $ha^{-1}$ fresh weight contains approximately 170 kg $ha^{-1}$ N in the shoots, leaves and stems. By comparison, a 15,000 kg $ha^{-1}$ dry matter silage corn crop removes 225 kg $ha^{-1}$ N which, under the minimum loss system, can be supplied by 3.2 manure units of dairy manure (from Table 10). Therefore, a broccoli crop of 12,000 kg $ha^{-1}$ fresh weight will require approximately 2.4 manure units of dairy manure calculated as follows:

$$\text{Manure Units for broccoli} = \frac{3.2 \times 170}{225} = 2.4$$

For each crop and yield indicated in Table 11, nitrogen removal values are provided for the harvested portion of the crop (that portion which is marketed) and 50% and 100% of the non-harvested portion (the refuse portion of the crop). If all of the non-harvested or refuse portion was left in the field and incorporated after the previous crop, use the figures in the 50% column. It is assumed that 50% of the nitrogen from this portion of the previous year's crop will be available during the current growing season. If all of the non-harvested portion was removed, or the nitrogen contained in the refuse portion of the previous crop is not considered for the current crop, use the figures in the 100% column.

**TABLE 10: MINIMUM LOSS APPLICATION RATES FOR TWO CROPS**

| Crop | Potential Yield ($t.ha^{-1}$) dry matter | Minimum Loss Manure Rate (manure units/ha) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Dairy Places | Swine Places | | | Poultry Places | |
| | | | Grower/ Finisher | Weaner | Farrow to Finish | Layer | Broiler |
| Silage | 15 | 3.2 | 19.8 | 9.7 | 2.7 | 550 | 578 |
| Corn | 18 | *3.8 | 23.8 | 11.6 | 3.2 | 628 | *660 |
| | 20 | *4.7 | *28.7 | *13.8 | *3.9 | *800 | *840 |
| Forage | 12 | 2.9 | 18.0 | 8.6 | 2.4 | 464 | 486 |
| Grasses | 14 | 3.7 | 22.3 | 10.7 | 3.0 | 610 | 640 |
| | 16 | *4.8 | *28.7 | *13.8 | *3.9 | *870 | *912 |

* Enough irrigation is added to eliminate any water deficit.
Assumed N content of corn and grass are 1.5% and 2.7% respectively.

To calculate the manure units required for a particular crop (under a minimum loss system), enter the appropriate values in the lines provided.

Nitrogen in harvested portion _____(1)*

Nitrogen in non-harvested portion _____(2)

Manure units for a 15 t ha$^{-1}$ silage corn yield _____(3)

$$\text{MANURE UNITS} = \frac{[(1)+(2)] \times (3)}{225} = \text{_____(4)}$$

**TABLE 11: YIELD AND NITROGEN REMOVAL VALUES FOR SELECTED CROPS [2]**

| CROP | YIELD | Nitrogen Removal (kg ha$^{-1}$) By Harvested Portion | Non-Harvested Portion 50% | Non-Harvested Portion 100% |
|---|---|---|---|---|
| | **Dry Weight Basis** | | | |
| Silage Corn | 15,000 kg ha$^{-1}$ | 225 | | |
| | 20,000 | 325 | | |
| Forage Grass | 12,000 | 250 | | |
| | 16,000 | 325 | | |
| **Cereals** | **As Harvested Basis** | | | |
| Barley | 3,000 kg ha$^{-1}$ | 50 | 20 | 40 |
| | 5,000 | 80 | 30 | 60 |
| Oats | 2,000 | 35 | 10 | 20 |
| | 4,000 | 70 | 20 | 40 |
| Wheat | 3,000 | 60 | 20 | 40 |
| | 5,000 | 100 | 30 | 60 |
| **Vegetables** | **Fresh Weight** | | | |
| Broccoli | 8,000 kg ha$^{-1}$ | 45 | 40 | 80 |
| | 12,000 | 60 | 55 | 110 |
| Brussels | 9,000 | 60 | 35 | 70 |
| Sprouts | 13,000 | 80 | 50 | 100 |
| Cabbage | 35,000 | 100 | 30 | 60 |
| | 60,000 | 170 | 50 | 100 |
| Carrots | 30,000 | 50 | 40 | 80 |
| | 40,000 | 70 | 50 | 100 |
| Cauliflower | 9,000 | 30 | 40 | 80 |
| | 16,000 | 45 | 55 | 110 |
| Sweet Corn | 10,000 | 45 | 35 | 70 |
| | 20,000 | 90 | 70 | 140 |
| Lettuce | 40,000 | 100 | | |
| | 60,000 | 150 | | |
| Onions | 45,000 | 100 | 20 | 40 |
| | 55,000 | 120 | 25 | 50 |
| Potatoes | 30,000 | 100 | 40 | 80 |
| | 50,000 | 170 | 65 | 130 |
| **Small Fruit** | | | | |
| Strawberries (establishment year) | Apply 50 kg ha$^{-1}$ prior to establishment | | | |
| Raspberries (production year) | 8,000 | 35 | 30 | 60 |
| | 13,000 | 60 | 50 | 100 |

* Number in ( ) refers to line number.

## APPLICATION RATE ADJUSTMENT FACTORS

On-farm manure management systems which differ substantially from the previously described minimum loss systems will result in increased nitrogen losses and less nitrogen available for crop production. In such cases, the rate of manure application must be increased or nitrogen must be supplied from fertilizers to meet crop nitrogen demands.

Other factors, such as soil nitrogen level, annual precipitation, and soil texture can have a major impact upon the rate of manure required to supply crop nitrogen demand.

Tables 12 to 16 on pages 10 and 11 specify manure handling practices, soil characteristics and locations in B.C., which are different than the Minimum Loss System and provide corresponding loss and adjustment factors. The minimum loss application rate (from Table 10 on page 8 or line (4) page 9) when multiplied by the appropriate factors indicates the application rate for a specific farm and its waste handling system.

**Example 1:**

**a) Farm System:**

- — Abbotsford dairy farm
- — liquid manure stored in an **uncovered concrete pit**
- — manure applied in spring with vacuum tanker and **no incorporation**
- — potential yield of silage corn is **15 tonnes per hectare.**

**b) Manure Units Required:**

= 3.2 (Minimum Loss System, Table 10) × Storage Factor (Table 13) × Time of Application Factor (Table 14) × Method of Spreading Factor (Table 15)

= 3.2 × 1.1 × 1.0 × 1.8

= 6.3 manure units per hectare

***NOTE:**
Crop N content [(1) + (2)] and soil N content must be used in Table 12 page 10 to select a 'Soil Nitrogen Factor'. The Crop N content (divided by 100) should also be entered on line (26) page 16 for calculating fertilizer N requirement.

## TABLE 12: SOIL NITROGEN[1] ADJUSTMENT FACTORS[2]

| SOIL N[3] | SOIL O.M.% | NITROGEN REMOVAL BY CROP (kg ha$^{-1}$) 50 | 75 | 100 | 125 | 150 | 175 | 200 | * 225 | ** 250 | 275 | 300 | *** 325 | 350 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .1 | 2.2 | 1.32 | 1.30 | 1.28 | 1.26 | 1.24 | 1.22 | 1.2 | 1.18 | 1.16 | 1.14 | 1.12 | 1.10 | 1.08 |
| .2 | 4.3 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| .3 | 6.5 | .68 | .7 | .72 | .74 | .76 | .78 | .8 | .82 | .84 | .86 | .88 | .9 | .92 |
| .4 | 8.7 | .36 | .4 | .44 | .48 | .52 | .56 | .6 | .63 | .68 | .72 | .76 | .8 | .84 |
| .5 | 10.9 | .04 | .1 | .16 | .22 | .28 | .34 | .4 | .45 | .52 | .58 | .64 | .7 | .76 |
| .6 | 13.0 | | | | | .04 | .12 | .2 | .26 | .36 | .44 | .52 | .6 | .68 |
| .7 | 15.2 | | | | | | | | .07 | .20 | .30 | .40 | .5 | .60 |
| .8 | 17.4 | | | | | | | | | .04 | .16 | .28 | .4 | .52 |
| .9 | 19.6 | | | | | | | | | | .02 | .16 | .3 | .44 |
| 1.0 | 21.7 | | | | | | | | | | | .04 | .2 | .36 |
| 1.1 | | | | | | | | | | | | | .1 | .28 |
| 1.2 | | | | | | | | | | | | | | .20 |

* Nitrogen removed by a 15 t ha$^{-1}$ silage corn crop.
** Nitrogen removed by a 12 t ha$^{-1}$ grass crop.
*** Nitrogen removed by a 20 t ha$^{-1}$ corn crop or a 16 t ha$^{-1}$ grass crop.
1. Soil nitrogen content is based on the top 20 cm of soil.
2. Soil nitrogen adjustment factors were estimated using the nitrogen behaviour simulation model.
3. Soil Kjeldahl nitrogen as a percent on a dry weight basis.

**NOTE:**

a) Soils with a high nitrogen content may supply most or all of the crop N requirement. However, crop producers may wish to apply some readily available N in the spring of the year, regardless of soil N content, to ensure that a nitrogen deficiency does not occur in the early part of the growing season.
b) Soil Kjeldahl nitrogen should be determined by analysis in a laboratory. However, this value can be estimated from the % organic matter value on the soil analysis report form. Multiply % organic matter by 0.046 [9] to obtain an estimated soil Kjeldahl nitrogen value.

## TABLE 13: LOSS FACTORS DUE TO COLLECTION AND STORAGE [6, 7, 8]

| Collection and Storage System | Loss Factor |
|---|---|
| *Dairy* | |
| Minimum Loss — covered, lined storage container | 1.0 |
| Uncovered, lined storage container | 1.1 |
| Manure stacks | 1.3 |
| Unlined earthen pit | 1.5 |
| Composted manure (factor includes spreading losses) | 1.8 |
| Anaerobically digested manure | 1.1 |
| *Swine* | |
| Minimum Loss — covered, lined tank | 1.0 |
| Flush: aeration tank separate from holding tank | 1.15 |
| Flush: full aeration of holding tank | 1.60 |
| Below floor pit (deep or shallow) | 1.24 |
| Earthen lagoon | 1.30 |
| Uncovered, lined tank | 1.12 |
| *Layers* | |
| Minimum Loss — scraped daily to deep pit, no fans | 1.0 |
| Scraped daily to deep pit, air circulating fans | 1.2 |
| Dropping boards, scraped to ventilated pit | 2.0 |
| Daily removal to covered storage, natural ventilation | 1.03 |
| *Broilers* | |
| Sawdust floor, daily removal to covered storage, natural ventilation | 1.0 |

## TABLE 14: LOSS FACTORS DUE TO TIME OF APPLICATION FOR MEDIUM TO FINE TEXTURED SOIL [6]

| Time of Application | Loss Factors Dairy | Swine | Poultry |
|---|---|---|---|
| *Minimum Loss System* (single spring application and applications when crop actively growing) | 1.00 | 1.00 | 1.00 |
| *Single Fall Application* | | | |
| October 9 | * 1.22 | * 1.25 | * 1.32 |
| October 27 | 1.15 | 1.14 | 1.19 |
| November 16 | 1.07 | 1.04 | 1.08 |
| *Split Spring/Fall Application* | | | |
| April 1 & October 9 | 1.15 | 1.12 | 1.15 |
| April 1 & October 27 | 1.08 | 1.08 | 1.07 |
| April 1 & November 16 | 1.03 | 1.03 | 1.03 |

* Indicates system may lose up to 90 kg ha$^{-1}$ N to groundwater per year if sufficient manure is applied to meet crop N requirement.

**NOTE:**

The greater losses apparent when comparing early October applications to mid November applications are a result of changing climatic conditions. The above figures are based on a system operating in Abbotsford. Here, fall temperatures remain high enough for the ammonia-N in the manure to be converted to nitrate ($NO_3^-$). The nitrate is subject to leaching to groundwater or denitrification over the winter. As fall progresses, temperatures lower and the rate of nitrification decreases. Also, less time is available for nitrification to occur and thus a progressively smaller amount of nitrate is present. It follows that less nitrate will be lost to groundwater.

If the moisture content of the soil is low, the nitrification process will be inhibited and less nitrate present to leach out over the winter. This is not the case in Abbotsford where fall and winter precipitation is generally high. As a result, there is sufficient moisture present to accomplish both nitrification and the leaching of nitrates to groundwater.

## TABLE 15: LOSS FACTORS DUE TO METHOD OF SPREADING [6, 7]

| Method of Spreading | Loss Factor |
|---|---|
| Minimum Loss (Subsurface injection) | 1.0 |
| *Dash Plate Vacuum Tanker* | |
| — incorporate immediately | 1.1 |
| — incorporate within 24 hours | 1.2 |
| — incorporate within 24 to 48 hours | 1.6 |
| — no incorporation | 1.8 |
| *High Spray Vacuum Tanker* | |
| — incorporate immediately | 1.2 |
| — incorporate within 24 hours | 1.3 |
| — incorporate within 24 to 48 hours | 1.7 |
| — no incorporation | 1.8 |
| *Solid Spreader* | |
| — incorporate immediately | 1.0 |
| — incorporate within 24 hours | 1.1 |
| — incorporate within 24 to 48 hours | 1.5 |
| — no incorporation | 1.8 |
| *Spray Irrigation* | |
| — incorporate immediately | 1.2 |
| — incorporate within 24 hours | 1.3 |
| — incorporate within 24 to 48 hours | 1.7 |
| — no incorporation | 1.8 |

## TABLE 16: LOSS FACTORS DUE TO FARM LOCATION OTHER THAN ABBOTSFORD [6]

| Farm Location | Loss Factor |
|---|---|
| Abbotsford (and similar coastal locations with greater than 75 cm rainfall per year). | 1.0 |
| Kamloops (and similar arid regions of B.C. receiving less than 30 cm of rainfall per year). Crop water requirements are fully met through irrigation. | 0.8 |

## TABLE 17: CALCULATION OF MANURE UNITS REQUIRED TO SUPPLY CROP NITROGEN REQUIREMENT

Enter the appropriate factors on the blank lines provided.

Minimum Loss Application Rate (Table 10 or from calculation on page 9). _____ (5)

**Minimum Loss Application Rate Adjustment Factors**

— Production Factor: _____ (6)
(Dairy Table 2)
(Weaner Table 5)
(Farrow to Finish Table 7)
(for other types of manure enter 1.0 on line (6))

— Soil Nitrogen Adjustment Factor (Table 12 page 10) _____ (7)

— Location Factor (Table 16) _____ (8)

**Minimum Loss Application Rate Loss Factors**

— Collection and Storage Loss Factor (Table 13 page 10) _____ (9)

— Time of Application Loss Factor (Table 14 page 10) _____ (10)

— Method of Spreading Loss Factor (Table 15 page 11) _____ (11)

**RATE OF MANURE (MR):**

= (5) × (6) × (7) × (8) × (9) × (10) × (11)

= Manure Units per hectare _____ (12)

## *TABLE 2: MILK PRODUCTION FACTORS

| Herd Average Milk Production kg/day | kg/305 days | kg/365 days | Adjustment Factors |
|---|---|---|---|
| 20 | 6100 | 7300 | 1.27 |
| 21 | 6405 | 7665 | 1.2 |
| 22 | 6710 | 8030 | 1.15 |
| 23 | 7015 | 8395 | 1.1 |
| 24 | 7320 | 8760 | 1.06 |
| 25.3 | 7716 | 9250 | 1.0 |

## *TABLE 5: WEANER PRODUCTION FACTORS (PRODUCTION/SOW PLACE)

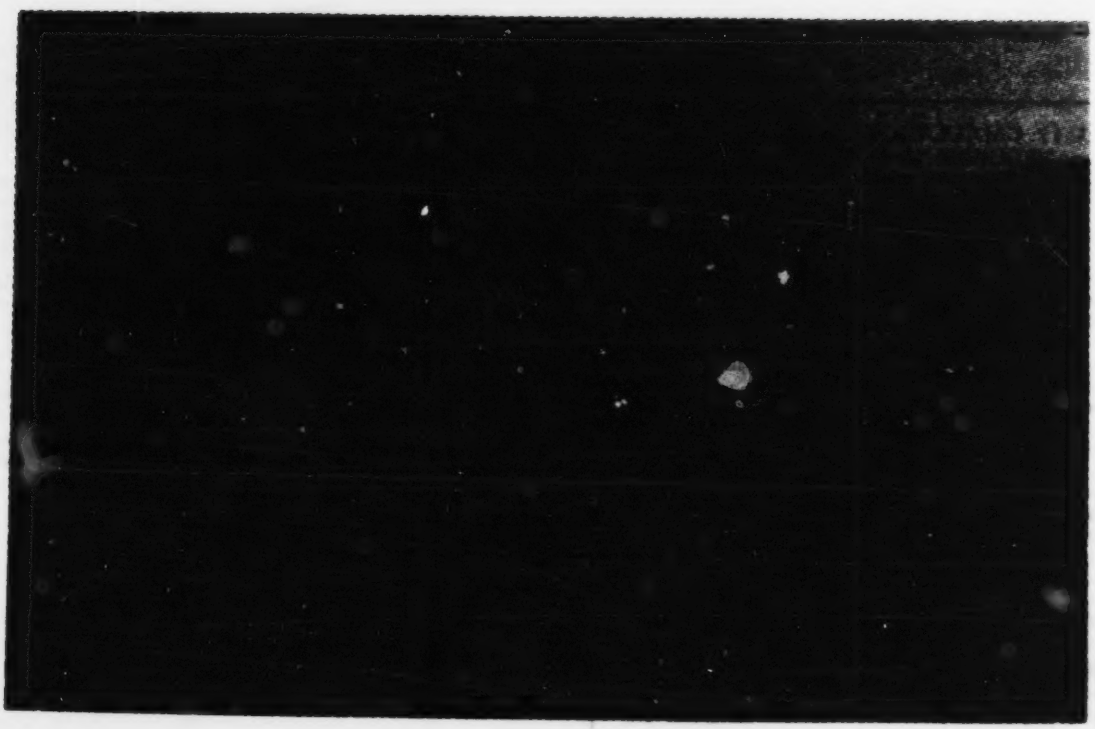
| Weaners Present at any one time (per sow place) | Weaners Marketed per year (per sow place) | Adjustment Factor |
|---|---|---|
| 2.4 | 13.8 | 1.10 |
| 2.8 | 16.1 | 1.08 |
| 3.2 | 18.4 | 1.00 |
| 3.6 | 20.7 | 0.95 |
| 4.0 | 23.0 | 0.91 |
| 4.4 | 25.3 | 0.86 |
| 4.8 | 27.6 | 0.81 |

## *TABLE 7: FINISHER PRODUCTION FACTORS (PRODUCTION/SOW PLACE)

| Weaners Present At Any One Time (per sow place) | Finishers Present At Any One Time (per sow place) | Finishers Marketed (per sow place/yr.) | Adjustment Factor |
|---|---|---|---|
| 2.4 | 4.0 | 13.8 | 1.26 |
| 2.8 | 4.6 | 16.1 | 1.11 |
| 3.2 | 5.3 | 18.4 | 1.00 |
| 3.6 | 6.7 | 20.7 | 0.91 |
| 4.0 | 7.3 | 23.0 | 0.83 |
| 4.4 | 7.9 | 25.3 | 0.75 |
| 4.8 | 8.5 | 27.6 | 0.68 |

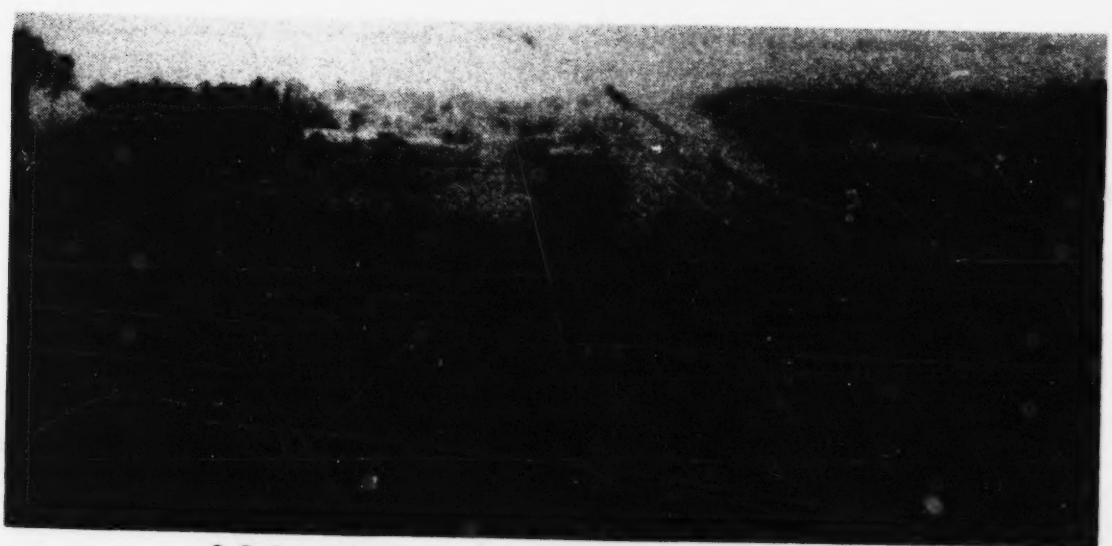
* These are duplicates of tables previously presented.

*5. Subsurface injection.*



*6. High spray vacuum tanker.*

*7. Spray irrigation equipment used for spreading liquid manure.*



*8. Surface application without incorporation results in high nitrogen losses.*

# VOLUME OF MANURE IN STORAGE AND SPREADER LOADS PER HECTARE

The actual volume or weight of manure (e.g. number of spreader loads per hectare) which must be applied to the land to meet the calculated manure units per hectare will vary considerably from one farm to another. Although individuals of each type of animal excrete similar quantities of waste and nitrogen, the quantities of stored manure changes according to each farm system. For example, the amount of dilution of dairy manure due to wash water and yard runoff, or the amount of drying of poultry manure due to ventilation and drying fans makes the final volume of waste available for application farm specific. Recommendations for manure application rates in terms of tonnes or litres per hectare are meaningless unless the moisture content of the manure is known. Thus, recommended rates are given in terms of manure units per hectare. If the moisture content of manure is known, Table 23 (page 21) provides approximate weights and volumes of a manure unit.

## CALCULATION OF THE SPREADER LOADS OF WELL MIXED MANURE TO APPLY PER HECTARE

Enter the appropriate values in the blank spaces provided.

Volume of Manure in Storage in cubic meters _____ (13)

Spreader Capacity in cubic meters _____ (14)

Manure Units in Storage: (from calculation on page 15) _____ (15)

Manure Units Required per Hectare (from line (12), page 11) _____ (16)

**1. Spreader Loads per Hectare Required to Meet Nitrogen Requirement of Crop:**

— Spreader loads to empty tank = (13)/(14) _____ (17)

— Hectares to receive manure = (15)/(16) _____ (18)

— Spreader loads per hectare = (17)/(18) _____ (19)

**2. Spreader Loads Required for a Specific Number of Hectares:**

— Spreader loads to empty tank = (13)/(14) _____ (20)

— Hectares to receive manure = _____ (21)

— Spreader loads per hectare = (20)/(21) _____ (22)

## TABLE 18: CALCULATION OF MANURE UNITS IN STORAGE

**1. Dairy manure units in storage:**
The number of manure units in storage at any one time is:
# of cows in milking herd × $\frac{\text{months of manure collection}}{12}$

= _____ (a)

If the manure from dry cows and heifers is added to the milking cow manure, the number of units should be increased by the following:
# of heifers × 0.4 × $\frac{\text{months of collection}}{12}$ = _____ (b)

# of dry cow places × 0.25 × $\frac{\text{months of collection}}{12}$

= _____ (c)

**Total dairy manure units in storage = (a) + (b) + (c)**
= _____

**2. Grower/Finisher manure units in storage:**
The number of manure units in storage at any one time is:
# of grower/finisher places X $\frac{\text{months of manure collection}}{12}$

= _____

**3. Weaner or farrow to finish manure units in storage:**
The number of manure units in storage at any one time is:
# of breeding sows X $\frac{\text{months of manure collection}}{12}$

= _____

**4. Layer manure units in storage:**
The number of manure units in storage at any one time is:
# of layers X $\frac{\text{months of manure collection}}{12}$

= _____

**5. Broiler manure units in storage:**
The number of manure units in storage at any one time is:
# of bird places X $\frac{\text{months of manure collection}}{12}$

= _____

# INORGANIC FERTILIZER REQUIREMENT

## INORGANIC NITROGEN FERTILIZER REQUIREMENT

The amount of nitrogen applied by manure may not be sufficient for the desired level of crop production. In such cases inorganic nitrogen is required to prevent a yield depression due to nitrogen deficiency. To calculate the rate of inorganic nitrogen needed to supplement the manure nitrogen, the following formula can be used. The formula is based on the assumption that for every incremental reduction in the amount of manure applied, a certain amount of fertilizer nitrogen is required to achieve desired crop yields.

$$\textbf{Fertilizer N requirement} = \left[100 - \left(\frac{\textbf{Ma}}{\textbf{Mr}} \times 100\right)\right] \times \textbf{SN X CN}$$

'Ma' is the manure application rate

— Ma = Manure Units in Storage (line (15), page 14) / Hectares Receiving Manure

— Ma = _____ manure units per hectare (23)

'Mr' is the manure units required (line (12), page 11).

— Mr = _____ manure units per hectare (24)

'$S_N$' is the 'Soil N Adjustment Factor' selected from Table 12 on page 10.

_____ (25)

'$C_N$' is the 'Crop N Removal Factor'. This is determined by dividing the crop N removal value selected from the top line of Table 12 on page 10 by 100 (e.g. 125 or 275 divided by 100).

_____ (26)

$$\text{Fertilizer N (kg ha}^{-1}) = \left[100 - \left(\frac{(23)}{(24)} \times 100\right)\right] \times (25) \times (26)$$

= _____ (27)

## INORGANIC PHOSPHORUS AND POTASSIUM FERTILIZER REQUIREMENT

Rates can be calculated using values entered on the following page.

$$\text{Fertilizer } P_2O_5 \text{ (kg ha}^{-1}) = (32) - [(30) \times (23)]$$

= _____

$$\text{Fertilizer } K_2O \text{ (kg ha}^{-1}) = (33) - [(31) \times (23)]$$

= _____

# DETERMINING THE MOST EFFICIENT COMBINATION OF MANURE AND INORGANIC FERTILIZER

From a least cost viewpoint, the rate of manure applied to an area of land should be that which minimizes the cost of chemical fertilizer while at the same time providing sufficient N, $P_2O_5$, and $K_2O$ for the desired crop yields. The following calculations are provided to assist in determining the combination of manure and inorganic fertilizer which will minimize cost.

*Step 1:* Enter the appropriate values on the lines provided

a) Hectares to receive manure (line (18), page 14) _____ (28)

b) Manure units in storage (line (15), page 14) _____ (29)

c) Manure $P_2O_5$ — (these values assume that ½ the total $P_2O_5$ in manure is available)
- 15 kg for each dairy manure unit
- 4.5 kg for each grower/finisher manure unit
- 9 kg for each weaner manure unit
- 32 kg for each farrow to finish manure unit
- 0.26 kg for each poultry manure unit

_____ (30)

d) Manure $K_2O$
- 117 kg for each diary manure unit
- 7 kg for each grower/finisher manure unit
- 14 kg for each weaner manure unit
- 50 kg for each farrow to finish manure unit
- 0.34 kg for each poultry manure unit

_____ (31)

e) Soil test recommendation
- $P_2O_5$ kg $ha^{-1}$ _____ (32)
- $K_2O$ kg $ha^{-1}$ _____ (33)

f) Manure units per hectare required to meet crop requirement for:
- N (line (12), page 11) _____ (34)
- $P_2O_5 = \frac{(32)}{(30)} =$ _____ (35)
- $K_2O = \frac{(33)}{(31)} =$ _____ (36)

g) Area that can be completely supplied with:
- N from manure $= \frac{(29)}{(34)} =$ _____ ha (37)
- $P_2O_5$ from manure $= \frac{(29)}{(35)} =$ _____ ha (38)
- $K_2O$ from manure $= \frac{(29)}{(36)} =$ _____ ha (39)

h) SN (line (25), page 16) _____ (40)
CN (line (26), page 16) _____ (41)

i) Cost per kg of:
- N _____ (42)
- $P_2O_5$ _____ (43)
- $K_2O$ _____ (44)

*Step 2:* For situations where all of the crop nutrient requirements for N, $P_2O_5$, and $K_2O$ are to be supplied by manure, the highest value among lines (34), (35), and (36) is the required manure application rate. Note that excess amounts of two of the nutrients will be applied and may cause pollution of ground water. The area that can be completely fertilized with manure is the lowest value among lines (37), (38), and (39).

*Step 3:* For situations where insufficient manure is available and some of the crop nutrient requirement must be supplied by inorganic fertilizer, the following steps will help determine the most efficient combination of manure and inorganic fertilizer:

3.1 Assume manure spread evenly over entire crop area.

a) Rate of fertilizer N (line (27), page 16) _____ kg $ha^{-1}$ (45)

b) Rate of fertilizer $P_2O_5 = [(35) - \frac{(29)}{(28)}] \times (30) =$ _____ kg $ha^{-1}$ (46)

c) Rate of fertilizer $K_2O = [(36) - \frac{(29)}{(28)}] \times (31) =$ _____ kg $ha^{-1}$ (47)

d) Cost of fertilizer
- N = (45) × (42) × (28) = $ _____ (48)
- $P_2O_5$ = (46) × (43) × (28) = $ _____ (49)
- $K_2O$ = (47) × (44) × (28) = $ _____ (50)

**Total cost of fertilizer = (48) + (49) + (50) = $ _____ (51)**

**Note:**
If line (45) equals or is less than zero do not complete 3.2.
If line (46) equals or is less than zero do not complete 3.3.
If line (47) equals or is less than zero do not complete 3.4.

3.2 Assume that the manure application rate will be on the basis of crop N requirement. Determine the extra inorganic N, $P_2O_5$, and $K_2O$ required to adequately fertilize the area to be cropped.

a) Amount of N required
$[(28) - (37)] \times 100 \times (40) \times (41) =$
_____ kg (52)

b) Amount of $P_2O_5$ required
— on manured area
$= [(35) — (34)] \times (30) \times (37) =$
_____ kg (53)
— on non-manured area
$= [(28) — (37)] \times (32) =$
_____ kg (54)

c) Amount of $K_2O$ required
— on manured area
$= [(36) — (34)] \times (31) \times (37) =$
_____ kg (55)
— on non-manured area
$= [(28) — (37)] \times (33) =$
_____ kg (56)

d) Cost of Fertilizer
— $N = (52) \times (42)$ $ _____ (57)
— $P_2O_5 = [(53) + (54)] \times (43)$
$ _____ (58)
— $K_2O = [(55) + (56)] \times (44)$
$ _____ (59)

**Total fertilizer cost**
**$= (57) + (58) + (59) =$ $ _____ (60)**

3.3 Assume that the manure application rate will be on the basis of crop $P_2O_5$ requirement. Determine the extra inorganic N, $P_2O_5$, and $K_2O$ required to adequately fertilize the area to be cropped.

a) Amount of N required
— on manured area
$= [100 - [\frac{(35)}{(34)} \times 100]] \times (40) \times (41) \times (38)$
$=$ _____ kg (61)
— on non-manured area
$= [(28) - (38)] \times 100 \times (40) \times (41)$
$=$ _____ kg (62)

b) Amount of $P_2O_5$ required
$= [(28) - (38)] \times (32) =$ _____ kg (63)

c) Amount of $K_2O$ required
— on manured area
$= [(36) - (35)] \times (31) \times (38)$
$=$ _____ kg (64)
— on non-manured area
$= [(28) - (38)] \times (33) =$ _____ kg (65)

d) Cost of Fertilizer
— $N = [(61) \times (62)] \times (42) =$
$ _____ (66)
— $P_2O_5 = (63) \times (43) =$
$ _____ (67)
— $K_2O = [(64) + (65)] \times (44) =$
$ _____ (68)

**Total fertilizer cost**
**$= (66) + (67) + (68) =$ $ _____ (69)**

3.4 Assume that the manure application rate will be on the basis of crop $K_2O$ requirement. Determine the extra inorganic N, $P_2O_5$, and $K_2O$ required to adequately fertilize the area to be cropped.

a) Amount of N required
— on manured area
$= [100 - [\frac{(36)}{(34)} \times 100]] \times (40) \times (41) \times (39)$
$=$ _____ kg (70)
— on non-manured area
$= [(28) - (39)] \times 100 \times (40) \times (41)$
$=$ _____ kg (71)

b) Amount of $P_2O_5$ required
— on manured area
$= [(35) - (36)] \times (30) \times (39)$
$=$ _____ kg (72)
— on non-manured area
$= [(28) - (39)] \times (32) =$ _____ kg (73)

c) Amount of $K_2O$ required
$= [(28) - (39)] \times (33) =$ _____ kg (74)

d) Cost of Fertilizer
— $N = [(70) + (71)] \times (42) =$
$ _____ (75)
— $P_2O_5 = [(72) + (73)] \times (43) =$
$ _____ (76)
— $K_2O = (74) \times (44) =$
$ _____ (77)

**Total fertilizer cost**
**$= (75) + (76) + (77) =$ $ _____ (78)**

*Step 4*: Compare cost values on lines (51), (60), (69), and (78). The lowest value will indicate the most efficient manure and fertilizer application program from a nutrient cost point of view.

3.1: _____ (51)
3.2: _____ (60)
3.3: _____ (69)
3.4: _____ (78)

Items corresponding to lowest value:

a) Hectares to manure
— If 3.1, line (28)
— If 3.2, line (37)
— If 3.3, line (38)
— If 3.4, line (39) _____ (79)

b) Rate of fertilizer on manured area
— N _____ kg/(79) = _____ kg $ha^{-1}$
— $P_2O_5$ _____ kg/(79) = _____ kg $ha^{-1}$
— $K_2O$ _____ kg/(79) = _____ kg $ha^{-1}$

c) Hectares to receive only fertilizer
— If 3.1, value is 0
— If 3.2, (28) – (37)
— If 3.3, (28) – (38)
— If 3.4, (28) – (39) _____ (80)

d) Rate of fertilizer on non-manured area
— N _____ kg/(80) = _____ kg $ha^{-1}$
— $P_2O_5$ _____ kg/(80) = _____ kg $ha^{-1}$
— $K_2O$ _____ kg/(80) = _____ kg $ha^{-1}$

# PHOSPHORUS AND POTASSIUM

The minimum loss manure application rates will apply a substantial portion of the $P_2O_5$ and $K_2O$ requirements of most crops. Manure management methods which increase nitrogen losses, compared to the minimum loss system, will increase the manure required to provide sufficient nitrogen for adequate crop production. These higher rates will often add more $P_2O_5$ and $K_2O$ than necessary. To efficiently use the $P_2O_5$ and $K_2O$ contained in various manures, application rates should not greatly exceed the minimum loss rate and any shortfall in nitrogen requirement should be added by chemical fertilizer.

Tables 19, 20 and 21 indicate the quantities of $P_2O_5$ and $K_2O$ contained in dairy, swine and poultry manure when applied at different rates. Note that only ½ of the total $P_2O_5$ in manure is available the year applied.

**TABLE 19: PHOSPHORUS AND POTASSIUM APPLIED IN DAIRY MANURE**

| Manure Application Rate (manure units $ha^{-1}$) | $P_2O_5$ (kg $ha^{-1}$) | $K_2O$ (kg $ha^{-1}$) |
|---|---|---|
| 2.0 | 60 | 234 |
| 3.0 | 90 | 350 |
| 4.0 | 120 | 468 |
| 6.0 | 180 | 702 |
| 8.0 | 240 | 936 |
| 10.0 | 300 | 1170 |
| 15.0 | 450 | 1755 |

**Assumptions:**

1. All urine and feces collected and stored in an impervious structure.
2. Losses of P and K between excretion and land application are negligible.
3. One cow place ingests 23 kg $yr^{-1}$ P and 110 kg $yr^{-1}$ K and excretes 13 kg $yr^{-1}$ P (30 kg $yr^{-1}$ $P_2O_5$) and 97 kg $yr^{-1}$ K (117 kg $yr^{-1}$ $K_2O$) [1].

**TABLE 20: PHOSPHORUS AND POTASSIUM APPLIED IN SWINE MANURE**

| Manure Application Rate (manure units $ha^{-1}$) | | | $P_2O_5$ | $K_2O$ |
|---|---|---|---|---|
| Grower/ Finisher | Farrow/ Weaner | Farrow/ Finish | (kg $ha^{-1}$) | |
| 10 | 5 | 1.4 | 90 | 70 |
| 20 | 10 | 2.7 | 180 | 140 |
| 30 | 15 | 4.1 | 270 | 210 |
| 40 | 20 | 5.5 | 360 | 280 |
| 50 | 25 | 6.8 | 450 | 350 |
| 60 | 30 | 8.2 | 540 | 420 |

**Assumptions:**

1. All urine and feces collected and stored in an impervious structure.
2. Losses of P and K between excretion and land application are negligible.
3. One grower/finisher place ingests 6 kg $yr^{-1}$ P and 7 kg $yr^{-1}$ K [10] and excretes 4.0 kg $yr^{-1}$ P (9 kg $yr^{-1}$ $P_2O_5$) and 5.8 kg $yr^{-1}$ K (7 kg $yr^{-1}$ $K_2O$).
   One breeding sow place in a farrow to weaner operation ingests 11.6 kg $yr^{-1}$ P and 15.4 kg $yr^{-1}$ K [10] and excretes 7.9 kg $yr^{-1}$ P (18 kg $yr^{-1}$ $P_2O_5$) and 11.7 kg $yr^{-1}$ K (14 kg $yr^{-1}$ $K_2O$).
   One breediing sow place in a farrow to finish operation ingests 45 kg $yr^{-1}$ P and 56 kg $yr^{-1}$ K [10] and excretes 28 kg $yr^{-1}$ P (64 kg $yr^{-1}$ $P_2O_5$) and 42 kg $yr^{-1}$ K (50 kg $yr^{-1}$ $K_2O$).

**TABLE 21: PHOSPHORUS AND POTASSIUM APPLIED IN POULTRY MANURE**

| Manure Application Rate (manure units $ha^{-1}$) | $P_2O_5$ (kg $ha^{-1}$) | $K_2O$ |
|---|---|---|
| 300 | 160 | 100 |
| 500 | 260 | 170 |
| 700 | 360 | 240 |
| 900 | 470 | 310 |
| 1100 | 570 | 370 |
| 1300 | 680 | 440 |

**Assumptions:**

1. All of the manure collected and stored in an impervious structure.
2. Losses of P and K between excretion and land application are negligible.
3. Each bird place ingests 0.26 kg $yr^{-1}$ P and 0.30 kg $yr^{-1}$ K [3] and excretes 0.23 kg $yr^{-1}$ P (0.52 kg $yr^{-1}$ $P_2O_5$) and 0.28 kg $yr^{-1}$ K (0.34 kg $yr^{-1}$ $K_2O$).

**TABLE 22: NITROGEN, PHOSPHATE, AND POTASH CONTENT OF ONE MANURE UNIT OF VARIOUS MANURES THAT HAVE BEEN MANAGED AS DESCRIBED FOR THE VARIOUS MINIMUM LOSS SYSTEMS**

| Type of Manure | Nutrient Content (kg per manure unit) | | |
|---|---|---|---|
| | N | $P_2O_5$ | $K_2O$ |
| Dairy | 90 | 30 | 117 |
| Grower/Finisher | 13.2 | 9 | 7 |
| Weaner | 27 | 18 | 14 |
| Farrow to Finish | 97 | 64 | 50 |
| Layer | 0.46 | 0.52 | 0.34 |
| Broiler | 0.46 | 0.52 | 0.34 |

**NOTE:**

a) Nitrogen content of manure when excreted will be higher than the values shown. Assumed losses after excretion are:
- — Dairy — 23%
- — Grower/Finisher — 23%
- — Weaner — 23%
- — Farrow to Finish — 23%
- — Layer — 43%
- — Broiler — 24%

b) Nitrogen content of manures managed differently than the Minimum Loss System will be lower than the values in the above table.

c) The values of $P_2O_5$ and $K_2O$ assume no loss during collection, storage and field application.

**TABLE 23: VOLUME AND WEIGHT OF ONE MANURE UNIT OF VARIOUS MANURES AS EXCRETED [1]**

| Composition as Excreted | | | Weight of One Manure Unit* | | Volume of One Manure Unit** | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Operation | Solids % | % $H_2O$ | tonnes | tons | litre | $M^3$ | $yd^3$ | Gal (Imp) | Gal (U.S.) |
| DAIRY | 12.7 | 87.3 | 22.1 | 24.3 | 22100 | 22.1 | 28.9 | 4861 | 5838 |
| SWINE | | | | | | | | | |
| Farrow/Finish | 9 | 91 | 19.6 | 21.6 | 19621 | 19.6 | 25.6 | 4311 | 5178 |
| Weaner | 9 | 91 | 7.6 | 8.4 | 7555 | 7.6 | 9.9 | 1672 | 2008 |
| Grower/Finisher | 9 | 91 | 2.3 | 2.5 | 2300 | 2.3 | 3.0 | 506 | 608 |
| POULTRY | | | | | | | | | |
| Layers | 24 | 76 | 0.051 | 0.056 | | | | | |
| Broilers | 23 | 77 | 0.029 | 0.033 | | | | | |

* Based on weight of feces and urine as voided.

** Assumes no bedding, or addition of washwater. If $H_2O$ content of manure is different than the above values, the weight or volume of one manure unit must be adjusted accordingly.

e.g., Dairy manure containing 5% solids.

a) Weight of manure unit $= \frac{12.7}{5\ (\%\ \text{solids})} \times 22.1$ tonnes

$= 56.1$ tonnes

b) Volume of manure unit $= \frac{12.7}{5} \times 4861$ imp. gal.

$= 12347$ imp. gal.

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# APPENDIX A:

# CALCULATION SHEETS

Users of the Manure Management Guidelines should make a number of copies of the calculation sheets on the following pages. These are provided so that the corresponding pages in the text of the Guidelines need not be filled in when one uses the Guidelines.

1. Calculation Sheet 1: Manure Units Required to Supply Crop Nitrogen Requirement.
2. Calculation Sheet 2: Spreader Loads of Well Mixed Manure to Apply per Hectare.
3. Calculation Sheet 3: Inorganic Nitrogen Fertilizer Requirement.
4. Calculation Sheet 4: Inorganic Phosphorus and Potassium Fertilizer Requirement.
5. Calculation Sheet 5: Determining the Most Efficient Combination of Manure and Inorganic Fertilizer.

# CALCULATION SHEET 1

# MANURE UNITS REQUIRED TO SUPPLY CROP NITROGEN REQUIREMENT

ENTER THE APPROPRIATE FACTORS ON THE BLANK SPACES PROVIDED.

Minimum Loss Application Rate (Table 10 or from calculation on page 9). _____(5)

**Minimum Loss Application Rate Adjustment Factors**

— Production Factor: _____(6)
(Dairy Table 2 page 11)
(Weaner Table 5 page 11)
(Farrow to Finish Table 7 page 11)
(For other types of manure enter 1.0 on line (6))

— Soil Nitrogen Adjustment Factor (Table 12 page 10) _____(7)

— Location Factor (Table 16 page 11) _____(8)

**Minimum Loss Application Rate Loss Factors**

— Collection and Storage Loss Factor (Table 13 page 10) _____(9)

— Time of Application Loss Factor (Table 14 page 10) _____(10)

— Method of Spreading Loss Factor (Table 15 page 11) _____(11)

**RATE OF MANURE (MR):**

= (5) × (6) × (7) × (8) × (9) × (10) × (11)

= **Manure Units per hectare** _____(12)

# CALCULATION SHEET 2

## SPREADER LOADS OF WELL MIXED MANURE TO APPLY PER HECTARE

ENTER THE APPROPRIATE VALUES IN THE BLANK SPACES PROVIDED.

Volume of Manure in Storage in cubic meters _____(13)

Spreader Capacity in cubic meters _____(14)

Manure Units in Storage: (line (15), page 14) _____(15)

Manure Units Required per Hectare (from line (12), page 11 or on Calculation Sheet 1) _____(16)

**1. Spreader Loads per Hectare Required to Meet Nitrogen Requirement of Crop:**

— Spreader loads to empty tank = (13)/(14) _____(17)

— Hectares to receive manure = (15)/(16) _____(18)

— Spreader loads per hectare = (17)/(18) _____(19)

**2. Spreader Loads Required for a Specific Number of Hectares:**

— Spreader loads to empty tank = (13)/(14) _____(20)

— Hectares to receive manure = _____(21)

— Spreader loads per hectare = (20)/(21) _____(22)

# CALCULATION SHEET 3

## INORGANIC NITROGEN FERTILIZER REQUIREMENT

ENTER THE APPROPRIATE VALUES IN THE BLANK SPACES PROVIDED.

— Manure Units in Storage (line (15), on page 14 or Calculation Sheet 2) _____(15)

— Hectares to Receive Manure _____(18)

— Manure Application Rate (Ma) $= \frac{(15)}{(18)} =$ _____(23)

— Manure Units Required (Mr) (line (12), on page 11 or Calculation Sheet 1) _____(24)

— Soil N Adjustment Factor ($S_N$) (Table 12, page 10 or line (7) Calculation Sheet 1) _____(25)

— Crop N Removal Factor ($C_N$) (determined by dividing the crop N removal value selected from Table 12 on page 10 by 100) _____(26)

**FERTILIZER N (kg ha$^{-1}$)**

$= [100 - [\frac{(23)}{(24)} \times 100)] \times (25) \times (26)$ _____(27)

# CALCULATION SHEET 4

# INORGANIC PHOSPHORUS AND POTASSIUM FERTILIZER REQUIREMENT

ENTER THE APPROPRIATE VALUES IN THE BLANK SPACES PROVIDED.

— MANURE $P_2O_5$ — (these values assume that 1/2 the total $P_2O_5$ in manure is available).

15 kg for each dairy manure unit

4.5 kg for each grower/finisher manure unit

9 kg for each weaner manure unit

32 kg for each farrow to finish manure unit

0.26 kg for each poultry manure unit _____(30)

— MANURE $K_2O$

117 kg for each dairy manure unit

7 kg for each grower/finisher manure unit

14 kg for each weaner manure unit

50 kg for each farrow to finish manure unit

0.34 kg for each poultry manure unit _____(31)

— SOIL TEST RECOMMENDATION

$P_2O_5$ kg $ha^{-1}$ _____(32)

$K_2O$ kg $ha^{-1}$ _____(33)

— MANURE APPLICATION RATE

(line (23), page 16 or on Calculation Sheet 3) _____(23)

FERTILIZER $P_2O_5$ (kg $ha^{-1}$)

= (32) − [(30) × (23)] = _____

FERTILIZER $K_2O$ (kg $ha^{-1}$)

= (33) − [(31) × (23)] = _____

# CALCULATION SHEET 5

# DETERMINING THE MOST EFFICIENT COMBINATION OF MANURE AND INORGANIC FERTILIZER

From a least cost viewpoint, the rate of manure applied to an area of land should be that which minimizes the cost of chemical fertilizer while at the same time providing sufficient N, $P_2O_5$, and $K_2O$ for the desired crop yields. The following calculations are provided to assist in determining the combination of manure and inorganic fertilizer which will minimize cost.

*STEP 1:* Enter the appropriate values on the lines provided

a) HECTARES TO RECEIVE MANURE (line (18), Calculation Sheet 3) _____(28)

b) MANURE UNITS IN STORAGE (line (15), page 14 or on Calculation Sheet 2) _____(29)

c) MANURE $P_2O_5$ — (these values assume that 1/2 the total $P_2O_5$ in manure is available)

— 15 kg for each dairy manure unit

— 4.5 kg for each grower/finisher manure unit

— 9 kg for each weaner manure unit

— 32 kg for each farrow to finish manure unit

— 0.26 kg for each poultry manure unit _____(30)

d) MANURE $K_2O$

— 117 kg for each dairy manure unit

— 7 kg for each grower/finisher manure unit

— 14 kg for each weaner manure unit

— 50 kg for each farrow to finish manure unit

— 0.34 kg for each poultry manure unit _____(31)

e) SOIL TEST RECOMMENDATION

— $P_2O_5$ kg $ha^{-1}$ _____(32)

— $K_2O$ kg $ha^{-1}$ _____(33)

f) MANURE UNITS PER HECTARE REQUIRED TO MEET CROP REQUIREMENT FOR:

— N (line (12), page 11 or on Calculation Sheet 1) _____(34)

— $P_2O_5 = \frac{(32)}{(30)} =$ _____(35)

— $K_2O = \frac{(33)}{(31)} =$ _____(36)

g) AREA THAT CAN BE COMPLETELY SUPPLIED WITH:

— N from manure = $\frac{(29)}{(34)}$ = _____ ha (37)

— $P_2O_5$ from manure = $\frac{(29)}{(35)}$ = _____ ha (38)

— $K_2O$ from manure = $\frac{(29)}{(36)}$ = _____ ha (39)

h) $S_N$ (line (25), page 16 or Calculation Sheet 3) _____ (40)

$C_N$ (line (26), page 16 or Calculation Sheet 3) _____ (41)

i) COST PER KG OF:

— N _____ (42)

— $P_2O_5$ _____ (43)

— $K_2O$ _____ (44)

*STEP 2:* For situations where all of the crop nutrient requirements for N, $P_2O_5$, and $K_2O$ are to be supplied by manure, the highest value among lines (34), (35), and (36) is the required manure application rate. Note that excess amounts of two of the nutrients will be applied and possibly cause pollution of ground water. The area that can be completely fertilized with manure is the lowest value among lines (37), (38), and (39).

*STEP 3:* For situations where insufficient manure is available and some of the crop nutrient requirement must be supplied by inorganic fertilizer, the following steps will help determine the most efficient combination of manure and inorganic fertilizer.

3.1 ASSUME MANURE SPREAD EVENLY OVER ENTIRE CROP AREA.

a) Rate of fertilizer N (line (27), page 16 or Calculation Sheet 3) _____ kg $ha^{-1}$ (45)

b) Rate of fertilizer $P_2O_5$

$$= [(35) - \frac{(29)}{(28)}] \times (30) =$$ _____ kg $ha^{-1}$ (46)

c) Rate of fertilizer $K_2O$

$$= [(36) - \frac{(29)}{(28)}] \times (31) =$$ _____ kg $ha^{-1}$ (47)

d) Cost of fertilizer:

— N = (45) × (42) × (28) = $_____(48)

— $P_2O_5$ = (46) × (43) × (28) = $_____(49)

— $K_2O$ = (47) × (44) × (28) = $_____(50)

**TOTAL COST OF FERTILIZER**

**= (48) + (49) + (50) =** **$_____(51)**

**NOTE:**

If line (45) equals or is less than zero do not complete 3.2.

If line (46) equals or is less than zero do not complete 3.3.

If line (47) equals or is less than zero do not complete 3.4.

3.2 Assume that the manure application rate will be on the basis of crop N requirement. Determine the extra organic N, $P_2O_5$, and $K_2O$ required to adequately fertilize the area to be cropped.

a) Amount of N required

$[(28) - (37)] \times 100 \times (40) \times (41) =$ _____ kg (52)

b) Amount of $P_2O_5$ required:

— on manured area
$= [(35) - (34)] \times (30) \times (37) =$ _____ kg (53)

— on non-manured area
$= [(28) - (37)] \times (32) =$ _____ kg (54)

c) Amount of $K_2O$ required:

— on manured area
$= [(36) - (34)] \times (31) \times (37) =$ _____ kg (55)

— on non-manured area
$= [(28) - (37)] \times (33) =$ _____ kg (56)

d) Cost of Fertilizer

— N = (52) × (42) = $_____ (57)

— $P_2O_5$ = [(53) + (54)] × (43) = $_____ (58)

— $K_2O$ = [(55) + (56)] × (44) = $_____ (59)

**TOTAL FERTILIZER COST =**

**= (57) + (58) + (59) =** **$_____ (60)**

3.3 Assume that the manure application rate will be on the basis of crop $P_2O_5$ requirement. Determine the extra inorganic N, $P_2O_5$, and $K_2O$ required to adequately fertilize the area to be cropped.

a) Amount of N required:

— on manured area

$$= [100 - [\frac{(35)}{(34)} \times 100]] \times (40) \times (41) \times (38) =$$

_____ kg (61)

— on non-manured area

$$= [(28) - (38)] \times 100 \times (40) \times (41) =$$

_____ kg (62)

b) Amount of $P_2O_5$ required

$$= [(28) - (38)] \times (32) =$$ _____ kg (63)

c) Amount of $K_2O$ required:

— on manured area

$$= [(36) - (35)] \times (31) \times (38) =$$ _____ kg (64)

— on non-manured area

$$= [(28) - (38)] \times (33) =$$ _____ kg (65)

d) Cost of Fertilizer

— $N = [(61) + (62)] \times (42) =$ $_____ (66)

— $P_2O_5 = (63) \times (43) =$ $_____ (67)

— $K_2O = [(64) + (65)] \times (44) =$ $_____ (68)

**TOTAL FERTILIZER COST**

**= (66) + (67) + (68) =** **$_____ (69)**

3.4 Assume that the manure application rate will be on the basis of crop $K_20$ requirement. Determine the extra inorganic N, $P_20_5$, and $K_20$ required to adequately fertilize the area to be cropped.

a) Amount of N required

— on manured area

$$= [100 - [\frac{(36)}{(34)} \times 100]] \times (40) \times (41) \times (39) =$$

_____ kg (70)

— on non-manured area

$$= [(28) - (39)] \times 100 \times (40) \times (41) =$$

_____ kg (71)

b) Amount of $P_2O_5$ required

— on manured area

$= [(35) - (36)] \times (30) \times (39) =$ _____ kg (72)

— on non-manured area

$= [(28) - (39)] \times (32) =$ _____ kg (73)

c) Amount of $K_20$ required:

$= [(28) - (39)] \times (33) =$ _____ kg (74)

d) Cost of Fertilizer

— N = $[(70) + (71)] \times (42) =$ $_____ (75)

— $P_20_5 = [(72) + (73)] \times (43) =$ $_____ (76)

— $K_20 = (74) \times (44) =$ $_____ (77)

**TOTAL FERTILIZER COST**

**= (75) + (76) + (77) =** **$_____ (78)**

STEP 4: Compare cost values on lines (51), (60), (69), and (78). The lowest value will indicate the most efficient manure and fertilizer application program from a nutrient cost point of view.

3.1: _____ (51)

3.2: _____ (60)

3.3: _____ (69)

3.4: _____ (78)

Items corresponding to lowest value

a) HECTARES TO MANURE

— If 3.1, line (28)

— If 3.2, line (37)

— If 3.3, line (38)

— If 3.4, line (39) _____(79)

b) RATE OF FERTILIZER ON MANURED AREA

— N _____ kg/(79) = _____ kg $ha^{-1}$

— $P_2O_5$ _____ kg/(79) = _____ kg $ha^{-1}$

— $K_2O$ _____ kg/(79) = _____ kg $ha^{-1}$

c) HECTARES TO RECEIVE ONLY FERTILIZER

— If 3.1, value is 0

— If 3.2, (28)–(37)

— If 3.3, (28)–(38)

— If 3.4, (28)–(39) _____(80)

d) RATE OF FERTILIZER ON NON-MANURED AREA

— N _____ kg/(80) = _____ kg $ha^{-1}$

— $P_2O_5$ _____ kg/(80) = _____ kg $ha^{-1}$

— $K_2O$ _____ kg/(80) = _____ kg $ha^{-1}$

# APPENDIX B:

# MANURE MANAGEMENT DATA SHEET

1.* Type of Manure (circle one): Dairy, Grower/Finisher, Weaner, Farrow to Finish, Layer, Broiler.

2.* Crops to be grown: _____

3. Previous Crop: _____
refuse incorporated into soil? ☐ Yes ☐ No

4. Yield expected: average, high

5.** Soil Nitrogen Content _____%
Soil Organic Matter Content _____%

6.* Collection and Storage System: _____

_____

7.* Time of Application (of each application to be considered):

1st _____ 2nd _____ 3rd _____

8.* Method of Spreading: _____
— incorporation? immediate, withing 24 hours, 24–48 hours, no incorporation

9. Farm location: _____

10. Production:

DAIRY (kg/day) _____

WEANER (weaners marketed per sow per year) _____

FINISHER (finishers marketed per sow per year) _____

11.* Volume of Manure in Storage: _____

12.* Spreader Capacity: _____

13.* DAIRY: Cows in Milking Herd _____

Heifers: _____ } if manure added to milking cow manure

Dry Cows: _____ }

GROWER/FINISHER: Grower/Finisher Places _____

WEANER OR FARROW TO FINISH: No. of Breeding Sows _____

LAYERS: No. of layers _____

BROILERS: No. of Bird Places _____

14.* Months of Collection (for each application considered):

1st _____ 2nd _____ 3rd _____

15.* Hectares to Receive Manure: _____

16.** Soil Test Recommendations (kg/ha): _____ $P_2O_5$

or desired rate of fertilizer _____ $K_2O$

* Essential to determine manure application rate.
** Essential to determine least cost combination of manure and fertilizer.

# APPENDIX C:

# CONVERSION FACTORS

1. Imperial and U.S. Volume Conversions

| | |
|---|---|
| cubic feet × 6.23 | = Imperial Gallons |
| cubic feet × 7.48 | = U.S. Gallons |
| cubic feet × 0.78 | = Imperial Bushels |
| cubic yards × 168 | = Imperial Gallons |
| cubic yards × 202 | = U.S. Gallons |
| cubic yards × 21 | = Imperial Bushels |

2. Imperial to Metric

| | |
|---|---|
| feet × 0.305 | = metres |
| yards × 0.9 | = metres |
| cubic feet × 0.28 | = cubic metres |
| cubic feet × 28.3 | = litres |
| cubic yards × 0.765 | = cubic metre |
| cubic yards × 765 | = litres |
| Imperial Gallons × 0.0045 | = cubic metres |
| Imperial Gallons × 4.55 | = litres |
| U.S. Gallons × 0.00378 | = cubic metres |
| U.S. Gallons × 3.78 | = litres |
| Acres × 0.4 | = hectares |
| cubic yards/acre × 1.9 | = cubic metres/hectare |
| bushel/acre × 0.09 | = cubic metres/hectare |
| Imperial Gallons/ acre × 0.011 | = cubic metres/hectare |
| ton/acre × 2.25 | = tonnes/hectare |

# APPENDIX D:

# PERCENT LOSS IN NITROGEN CONTENT OF MANURE CORRESPONDING TO VARIOUS LOSS FACTORS

| LOSS FACTOR | % LOSS | LOSS FACTOR | % LOSS |
|---|---|---|---|
| 1.0 | 0 | 1.9 | 47% |
| 1.1 | 9% | 2.0 | 50% |
| 1.2 | 17% | 2.5 | 60% |
| 1.3 | 23% | 3.0 | 67% |
| 1.4 | 29% | 3.5 | 71% |
| 1.5 | 33% | 4.0 | 75% |
| 1.6 | 38% | 4.5 | 78% |
| 1.7 | 41% | 5.0 | 80% |
| 1.8 | 44% | | |

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